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MODELING AND OPTIMAL ALLOCATION IN HEALTHCARE PLANNING USING R

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ABSTRACT

Due to the continuously changing patient loads in hospitals either private or government the problem increases with overtime assigning different surgeries, allocation of beds, time hours etc for various medical services in hospitals. These problems can be effectively solved by using optimization techniques. In this paper a linear programming problem (LPP) is formulated and is used to determine the optimal combination of different surgeries performed in a private hospital that maximizes the total profit contributed by patients. The optimal solution of the formulated LPP is obtained using Branch and Bound method through R software.

KEYWORDS: Optimal Combination, Branch And Bound Method, Linear Programming Problem and R Software

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Original Article

INTRODUCTION

In health services sector either private or government hospitals optimization techniques play an important role towards achieving their goals. The healthcare has also suffered several downfalls, while the government trying to address the all ranging issues. Poor allocation of different surgeries may cause longer waiting time and can also worsen of the different patients diseases. Sodaghiani(1998) addresses that a hospital is an institution for healthcare, which is able to provide complete satisfaction and complex services of patients. Day by Day with the increase in number of patients results in rising cost of health services, with the limiting bed availability and need to contain the rising health costs have intensified the search for alternatives to conventional hospitalization Schwartzman (2001). Thus the challenges in improving the healthcare quality may cause increase in cost with the reduction of medical error, and increases efficiency of healthcare services. Lajjavardi (1382) shows that how one minimizes the patients waiting time without incurring additional costs. Different authors like (Chassin (1998), Represent(2003), Bagust (1999), Ward (2004)) worked out how the resources can be utilized in the most effect and economic way in healthcare planning.

The main objective of this article is to determine the optimal combination of different surgeries such that the total profit contributed by patients is maximum. In order to obtain the optimal solution of the formulated LPP, the solution is obtained by using Branch and Bound method through R software. Linear programming is an optimization method applicable for the solution of problems in which the objective function and the constraints appear as linear function of the decision variables. The constraint equations, in a linear programming from may be in the form of inequalities or equalities. In other words linear programming is a mathematical programming technique to optimize performance under a set of resource constraints as specified by an organization.

Mathematical Formulation of Linear Programming Problem (LPP)

The general LPP (or model) with n decision variables and m constraints can be stated in the following form

$$\begin{aligned} &Optimize \quad Z = C_1 X_1 + \ldots + C_n X_n && (A)\\ &subject\ to \\ &\qquad a_{11} X_1 + \ldots + a_{1n} X_n \ (\leq, =, \geq)\ b_1 \\ &\qquad a_{21} X_1 + \ldots + a_{2n} X_n \ (\leq, =, \geq)\ b_2 && (B)\\ &\qquad \ldots \qquad\qquad \ldots \\ &\qquad a_{m1} X_1 + \ldots + a_{mn} X_n \ (\leq, =, \geq)\ b_m \\ &and \quad X_1 \ldots, X_n \geq 0 \ ; \ (i = 1, 2, \ldots, m,\ j = 1, 2, \ldots, n) && (C) \end{aligned}$$

The above general LPP can be written as

$$Optimize\ Z = \sum_{j=1}^{n} C_j X_j$$

$$subject\ to$$

$$\sum_{i=1}^{m} \sum_{j=1}^{n} a_{ij} X_j \ (\leq, =, \geq)\ b_i$$

$$and \quad X_j \geq 0; \quad (i = 1, 2, \ldots, m,\ j = 1, 2, \ldots, n)$$

Where,

(A) =objective function, is an expression representing the total profit or cost of carrying out a set of activities at some levels. It can be either a maximization type or minimization type.

(B) = set of constraints, is a kind of restriction on the total amount of a particular resource required to carry out activities at various levels.

(C) = non-negative restrictions/constraints. Each and every decision variable in the LPP is a non-negative variable.

$C_j's$ = Objective function coefficients representing the profit per unit or cost per unit of carrying out an activity.

X_j = Decision variable representing the level of achievement of a particular course of action.

a_{ij} = The technology coefficient is the amount of resource i required for the activity j.

b_i = Resource availability is the amount of resource i during the planning period.

In the above general LPP, if either (A) or some (B) or both are non linear. Then the problem is said to be non linear programming problem (NLPP). The problem which does not involve any constraint is known as unconstrained programming problem.

Numerical Illustration

To illustrate an application of linear programming in Healthcare Planning, Let us assume that a Hospital has different departments and only four surgical departments performing different surgery. The performance of these surgeries is constrained by four resources: (i). Waiting room (WR) hours (ii).Operating Room (OR) hours (iii). Recovery room (RR) bed hours and (iv). Surgical services (SS). The capacity hours of WR, OR, RR and SS are 750 hours, 1000 hours, 1300 hours and 630 hours respectively for performing the different surgeries. Now, the director of the hospital is in a position to determine the optimal combination of surgical patients that maximizes the profit contributed by Patients with different surgeries. The required information is given below:

Table 1

	Survival Patients			
	λ_1	λ_2	λ_3	λ_4
WR	5	7	9	4
OR	4	6	5	7
RR	3	5	4	6
SS	6	3	2	5

Where,

λ_1 denotes the number of δ_1 type patients

λ_2 denotes the number of δ_2 type patients

λ_3 denotes the number of δ_3 type patients and

λ_4 denotes the number of δ_2 type patients

Let the average contribution to profit by δ_1, δ_2, δ_3 and δ_2 patients are \$20, \$22, \$21 and \$19 respectively. Thus in order to determine the optimal combination of surgical patients that maximizes the total profit contributed by Patients with different surgeries. The above problem is formulated as Linear Programming Problem and the solution is obtained by solving the formulated problem using Branch and Bound method through R software.

integ.lp<-lp("max",objective.in=c(20,22,21,19),const.mat=matrix(c(5,7,9,4,4,6,5,7,3,5,4,6,6,3,2,5),nrow=4), const.rhs=c (750,1000,1300,650),const.dir=c("<=","<=","<=","<="),int.vec=c(1,4))

> integ.lp

> integ.lp$solution

The optimal value is 3059.5

The optimal allocation is 128.0 0.0 14.0 11.0

From the optimal solution, δ_1 type patients contribute the most profit to the Hospital. Therefore the best way is to treat only δ_1 type patients. The optimal combination is (λ_1 λ_3 and λ_4) type patients i.e we have to treat (128 patients of δ_1 type surgery, 14 patients of δ_2 type surgery, and 14 patients of δ_4 type surgery). The total profit

contributed by optimal combinations of these surgeries is $3059.5.

CONCLUSIONS

The demands for efficient decisions in healthcare planning in private hospitals and related to resource allocation problems shows the application of optimization techniques in these problems. This paper uses the integer linear programming approach (ILPA) to determine the optimal allocation. Results shown above that Branch and Bound method managed to obtain the optimal value and optimal combination that meets the objective of the problem and the related constraints.

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